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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 409

EFFECT OF AGING ON TAUT RUBBER DIAPHRAGMS

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SUMMARY

As part of an investigation of special compositions of rubber suitable for use as diaphragms for aircraft instruments, six samples were used as taut diaphragms in instruments and allowed to age for five years. Two of the instruments were in operating condition after this period of time and one had remarkably little change in performance. In making the rubber tetramethyl thiuram disulphide was employed as a vulcanizing agent.

INTRODUCTION

It is recognized that rubber with good aging characteristics would be of value as a material for making diaphragms for sensitive pressure indicators, owing to its large deflections as compared with other materials commonly used. Rubber diaphragms which were used previous to 1924, have performed satisfactorily for a short period of time, but owing to the rapidity with which the rubber deteriorated, the instruments required frequent recalibrations and ultimately became unfit for use in a much shorter time than is desirable.

As a contribution toward solving this problem, the Bureau of Standards, with the financial assistance of the National Advisory Committee for Aeronautics, investigated in 1924, the behavior of a number of compositions of rubber containing accelerators at that time known. These samples were prepared at the Bureau of Standards by Dr. A. T. McPherson and were tested by the senior author and C. T. Buckingham. Six of the compositions having the best performance from those prepared and tested were used as diaphragms in air-speed indicators and tested over an additional aging period of five years. Data were obtained on four of these instruments which are briefly presented in this report.

COMPOSITION OF RUBBER

The composition of the rubber samples on which data were obtained as diaphragms, is given in Table I. The identification number of the instrument in which each diaphragm was installed for test is also given in the table.

TABLE I

Composition of Rubber and Vulcanization Data

Material	Instrument No.			
	1	14	15	16
	Per cent by weight			
Rubber (smoked sheet)	85.75	85.75	87.75	80.0
Zinc oxide	9.0	9.0	9.0	10.0
Tetramethylthiuram disulphide (Tuads)	3.0	3.0	3.0	10.0
Sulphur	0.25	0.25	0.25	-
Methylamino-para-phenol sulphate (Metol)	2.0	2.0	-	-
Time of vulcanization in minutes	5	3	25	60
Temperature of vulcanization in °C	141	141	121	127

Metol was employed as an ingredient with the thought that it might function as an antioxidant. None of the commercial antioxidants now used in rubber were available at the time these samples were prepared.

DESCRIPTION OF INSTRUMENTS

The samples were attached while taut to mounting rings in the manner described by Eaton and Buckingham. (Reference 1.) Each mounting ring and diaphragm was then installed in the case of an Ogilvie air-speed indicator. A view of a diaphragm in one of the instruments is shown in Figure 1.

The dates when the rubber was made and installed in the instruments are given in Table II. The range of each instrument and the corresponding pointer deflection in degrees of arc are also given in the table.

TABLE II

Instrument Ident. No.	Angular motion of pointer Degrees	Instrument range Inches of water	Rubber made	Diaphragm mounted in instrument
1	*	11.2	Jan., 1924	Feb., 1926
14	315	11.2	Jan., 1924	July, 1925
15	315	7.1	Jan., 1924	July, 1925
16	290	12.7	Sept., 1924	July, 1925

The diameter of each diaphragm was 84 millimeters (3.3 inches). The tip of the pointer of these instrumonts has a motion which is 23 times the deflection of the diaphragm, which is a comparatively small multiplication factor. The radius of the pointer to the tip is 41 mm (1.6 in.).

DESCRIPTION AND RESULTS OF TESTS

It was planned to have the instruments in service at the Langley Memorial Aeronautical Laboratory and to check the condition of the rubber by testing the instruments pe-

*Not obtained; taken as 300 degrees.

riodically. It is not known how much service use the instruments received but this factor is of probably little significance compared to the effect of lapse of time and temperature. The temperature during the summer months can be taken as the air temperature at the above laboratory at Langley Field, Hampton, Virginia.

In each test the diaphragms of the instruments were subjected to a number of differential pressures, first with the pressure increasing, and then with the pressure decreasing. These pressures were measured by means of a suitable manometer. The instrument reading was indicated on a scale graduated in units of air speed which were without difficulty converted to units of pressure, thus obtaining a reading directly proportional to the deflection of the diaphragm. The instruments were given this test while at room temperature (25°C) and at -10°C.

All of the instruments were given the first series of tests in 1926, two were again tested in 1927, and the remaining two in 1931. There were six instruments originally, two of which proved defective mechanically during the tests. Instrument No. 15 could not be tested in 1931, as its diaphragm had become useless, a rupture along the circumference having occurred.

The curve showing the errors for instrument No. 14 given in Figure 2, is typical of the curves obtained.

A summary of the test results is given in Table III.

The average increase in stiffness due to the lapse of time given in Table III is the difference in the slopes of the curves for increasing pressures obtained at the beginning and the end of the time interval. Thus, for instrument No. 14, the value at room temperature is the difference in slope of lines A and B in Figure 2.

The average increase in stiffness with decrease in temperature was determined similarly. For instrument No. 14 the value for 1931 is the difference in slope of lines A and C in Figure 2 and for 1926, the difference in slope of lines B and D.

The zero shift with the lapse of time is given in terms of pointer motion in degrees of arc. The prefix H means that the reading increased with time and L, that it decreased. In Figure 2, the ordinate E gives the zero shift in units of pressure, which has been converted into degrees of pointer motion using the data of Table II and on the assumption of a straight line relation between diaphragm deflection and differential pressure.

The hysteresis is the difference in the errors at a given reading of the instrument obtained first when the pressure was increased to the maximum and then when decreased to zero again. Thus in Figure 2, F_1, F_2, etc. are values of the hysteresis. The average hysteresis in per cent of range is the average of the hysteresis at equal intervals of the reading between the first and maximum reading divided by the maximum reading. Thus in Figure 2, the average hysteresis in the upper curve is

$$\frac{F_1 + F_2 - - - F_7 \; (= 0)}{7}$$

This value, when divided by 12.7, the maximum reading in pressure units, and multiplied by 100, gives 1.0, the quantity reported in Table III.

TABLE III

	Instrument No.			
	1	14	15	16
Average increase in stiffness in per cent from 1926 to 1927,				
at +25°C	+3.1	-	+1.5	-
at -10°C	+8.1	-	-1.5	-
from 1926 to 1931 at +25°C	-	0	-	-8.0
at -10°C	-	0	-	-3.7
Average increase in stiffness in per cent from temperature of +25°C to -10°C in 1926	+2.6	+2.5	+7.9	-0.8
in 1927	+7.6	-	+4.9	-
in 1931	-	+2.5	-	+3.5
Zero shift in degrees of pointer deflection from 1926 to 1927				
at +25°C	0.1H	-	3H	-
at -10°C	0	-	3L	-
from 1926 to 1931 at +25 C	-	3H	-	2H
at -10 C	-	2H	-	0.0

TABLE III (cont.)

Average hysteresis in per cent of range in 1926 to +25°C	-	0.8	-	0.1
and at -10°C	-	-	-	-
in 1927 at +20°C	0.4	-	0.1	-
and at -10°C	2.4	-	3.8	-
in 1931 at +25°C	-	1.0	-	0.4
and at -10°C	-	1.0	-	0.3

DISCUSSION

The data given in Table III are of value principally as a yardstick with which to compare the aging characteristics of rubber compositions available in 1924 with the best of those now available for test. The rubber installed in instrument No. 14 apparently has the best performance; in fact, no appreciable change in calibration or other characteristics of instrument performance were observed. It should be noted, however, that a slight change in calibration had been observed during the first year of the life of the rubber.

Not enough data are available to warrant any correlation between the specific composition of the diaphragms and their performance. Thus, for example, the composition of the rubber used in instrument No. 1 and instrument No. 14 are identical except for the slight difference in time of vulcanization but the performance of the two instruments differs far more than appears reasonable. A further point which may or may not be significant is the fact that the stiffness increased in the case of instruments Nos. 1 and 15, while on the other hand it decreased in the case of instrument No. 16. This may be partly caused by differences in the initial tension under which they are mounted. This tension may be reduced by the "set" of the rubber which reduces the stiffness of the diaphragm. The increase in stiffness is caused by oxidation of the rubber.

REFERENCE

1. Eaton, H. N., and Buckingham, C. T.: Nonmetallic Diaphragms for Instruments. T.R. No. 206, N.A.C.A., 1925.

Bureau of Standards,

Washington, D. C., November 30, 1931.

Fig. 1 View of rubber diaphragm mounted in an instrument. Note the simple arrangement for multiplying the motion of the diaphragm.

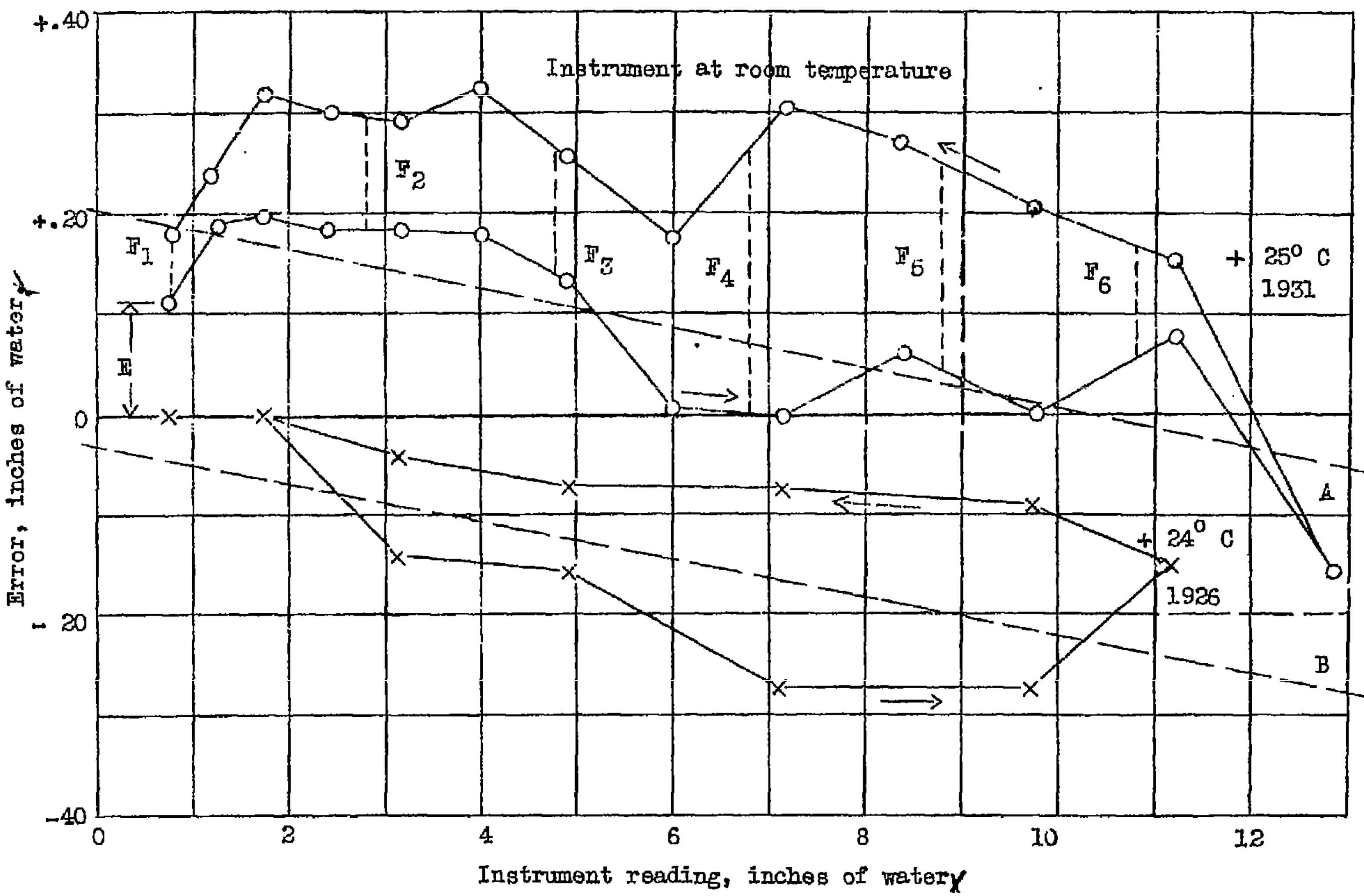
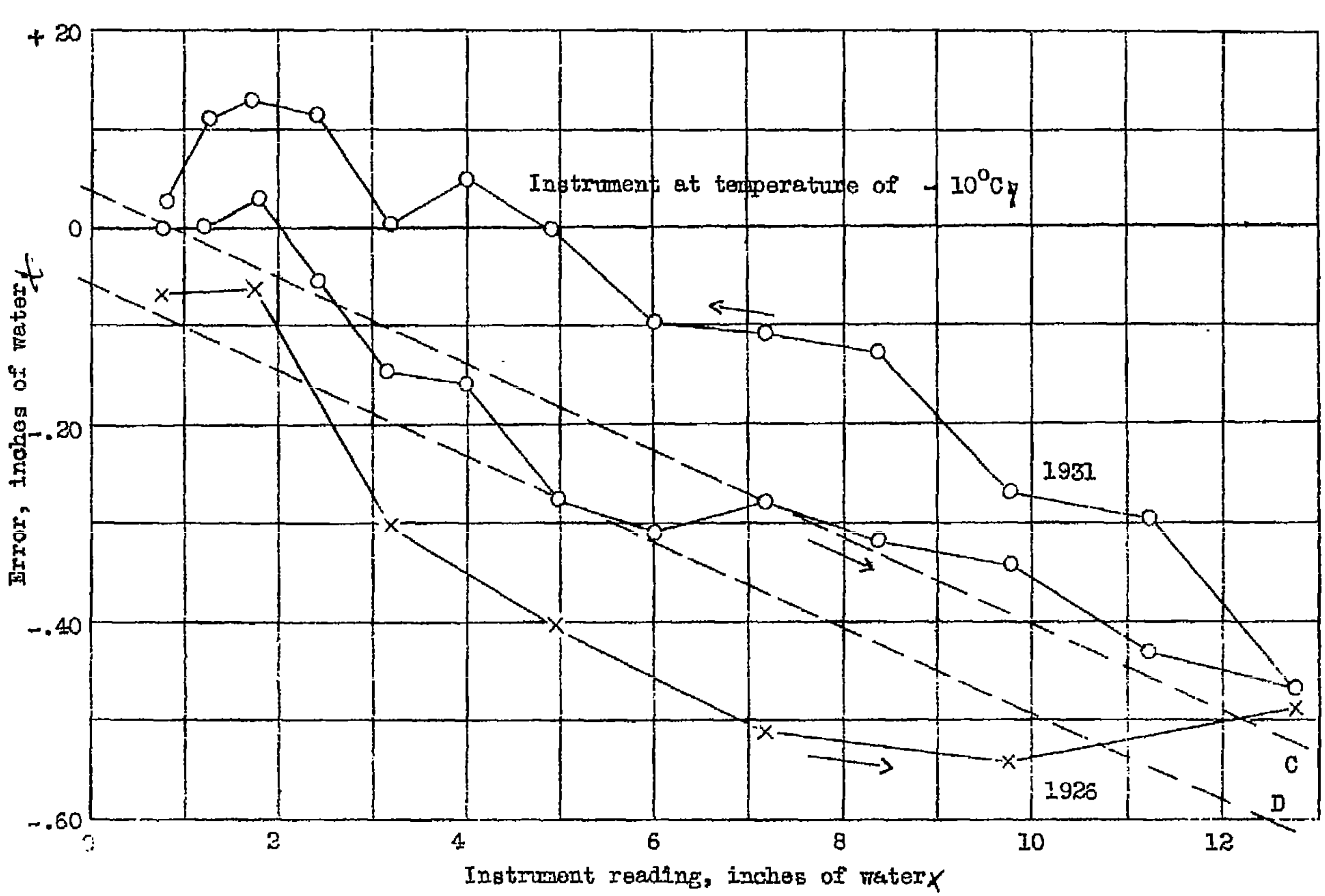


Fig. 2 (Continued on next page)

Performance of instrument No. 14.



(Continuation of Fig. 2)
Performance of instrument No. 14.